

WHAT IS CLAIMED IS:

1 1. A method for operating a fuel cell that generates an anode gas
2 including oxidizable components comprising receiving the anode gas from the fuel cell at an
3 elevated temperature, adding oxygen to the anode gas to form an oxidizable anode gas
4 mixture, heating the oxygen when a temperature of the mixture drops to below a temperature
5 at which the combustible components can be catalytically oxidized to thereby give the
6 mixture a temperature at which the combustible materials catalytically oxidize, catalytically
7 oxidizing the mixture to form an effluent, thereafter heating the effluent during at least
8 portions of the time when the fuel cell generates electricity, and heating the fuel cell with the
9 effluent.

1 2. A method according to claim 1 wherein heating comprises generating
2 an air flow, heating the air flow, and thereafter mixing the air flow with the anode gas to form
3 the mixture.

1 3. A method according to claim 2 including exchanging heat between the
2 air flow and the anode gas prior to mixing the air flow with the anode gas.

1 4. A method according to claim 3 wherein exchanging heat comprises
2 forming first and second flow paths for the anode gas and the air flow and separating the flow
3 paths by a heat exchange medium to transfer heat between the anode gas and the air flow so
4 that the temperatures of the anode gas and the air flow become more equal, and thereafter
5 merging the anode gas and the air flow to form the mixture.

1 5. A method according to claim 4 including selecting a length of the flow
2 paths so that substantially no portions of the mixture are above an auto-ignition temperature
3 of the combustible components in the anode gas at a predetermined highest temperature of
4 the anode gas encountered during the operation of the fuel cell.

1 6. A method according to claim 1 including modulating a heat output that
2 is generated for heating the anode gas to compensate for variations in at least one of the
3 temperature of the anode gas and a proportion of the combustible components in the anode
4 gas.

1 7. A method according to claim 6 including independently modulating
2 the heat output during heating the oxygen and a heat output generated for heating the effluent.

1 8. A method according to claim 1 including buffering the anode gas prior
2 to adding oxygen to compensate for fluctuations in at least one of the proportion of
3 combustible components in the anode gas and a temperature of the anode gas.

1 9. A method of operating a fuel cell which generates an anode gas that
2 includes an oxidizable component comprising flowing the anode gas through a first flow path
3 of a heat exchanger having first and second flow paths separated by a heat exchange member,
4 directing an air flow through the second flow path of the heat exchanger, heating the air flow
5 upstream of the heat exchanger, permitting a heat exchange between the anode gas and the air
6 flow in the first and second flow paths to thereby decrease a temperature differential between
7 the anode gas and the air flow, thereafter mixing the anode gas and the air flow downstream
8 of the flow paths to form a mixture, directing the mixture through a catalytic oxidizer for
9 oxidizing the oxidizable component in the anode gas and generating heat, flowing an effluent
10 from the catalytic oxidizer to the fuel cell, and at least at times during the operation of the
11 fuel cell heating the effluent from the catalytic oxidizer before the effluent reaches the fuel
12 cell.

1 10. A method according to claim 9 including selecting a heat input to the
2 air flow and a length of the first and second flow paths so that substantially all portions of the
3 mixture downstream of the flow paths have a temperature that is below an auto-ignition
4 temperature of the oxidizable component in the anode gas.

1 11. A method according to claim 10 wherein heating comprises heating the
2 air flow sufficiently to maintain a temperature of the mixture at which the oxidizable
3 component of the anode gas oxidizes in the catalytic oxidizer.

1 12. A method according to claim 11 wherein heating is performed
2 intermittently.

1 13. Apparatus for continuously operating a fuel cell and extracting heat
2 from an oxidizable component in an anode gas generated by the fuel cell comprising a heat
3 exchanger in fluid communication with the fuel cell for flowing the anode gas through a first

4 portion of the heat exchanger, the heat exchanger being further in fluid communication with a
5 source of an oxygen-containing gas and having a second portion through which the oxygen-
6 containing gas flows, whereby the temperatures of the anode gas and the oxygen-containing
7 gas tend to equalize in the heat exchanger, a downstream end of the heat exchanger being in
8 fluid communication with a space where the anode gas and the oxygen-containing gas mix
9 and form a mixture of anode gas and oxygen-containing gas, a first burner located upstream
10 of the heat exchanger for heating the oxygen-containing gas, a catalytic oxidizer in fluid
11 communication with the space receiving and oxidizing the mixture, the catalytic oxidizer
12 emitting a heated effluent, a conduit for directing at least a portion of the heated effluent from
13 the catalytic oxidizer back to the fuel cell, and a second burner for heating the effluent during
14 at least portions of the time when the fuel cell is operating.

1 14. A heat exchanger according to claim 13 including a controller that
2 independently modulates a heat output generated by the first and second burners.

1 15. Apparatus according to claim 13 wherein the heat exchanger comprises
2 first and second parallel conduits.

1 16. Apparatus according to claim 15 wherein the heat exchanger comprises
2 an outer tubular member extending in the flow direction of the oxygen-containing gas and a
3 plurality of spaced-apart pipes extending generally parallel to the tubular member and having
4 openings proximate downstream ends of the pipes which are in fluid communication with the
5 space, one of the tubular member and the pipes being in fluid communication with the
6 oxygen-containing gas flow downstream of the first burner and the other one of the tubular
7 member and the pipes being in fluid communication with the fuel cell for receiving the anode
8 gas so that the mixture is formed in the space after the temperature differential between the
9 anode gas and the oxygen-containing gas has been reduced to thereby prevent the formation
10 of auto-igniting hot spots in the mixture.

1 17. Apparatus according to claim 16 wherein the pipes are arranged
2 proximate an outer wall of the tubular member.

1 18. Apparatus according to claim 17 including a deflector in the flow of
2 the oxygen-containing gas located upstream of the pipes for directing the oxygen-containing
3 gas radially outward towards the pipes arranged proximate the outer wall of the tubular
4 member.

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19. Apparatus according to claim 13 wherein the source is a source of air.